

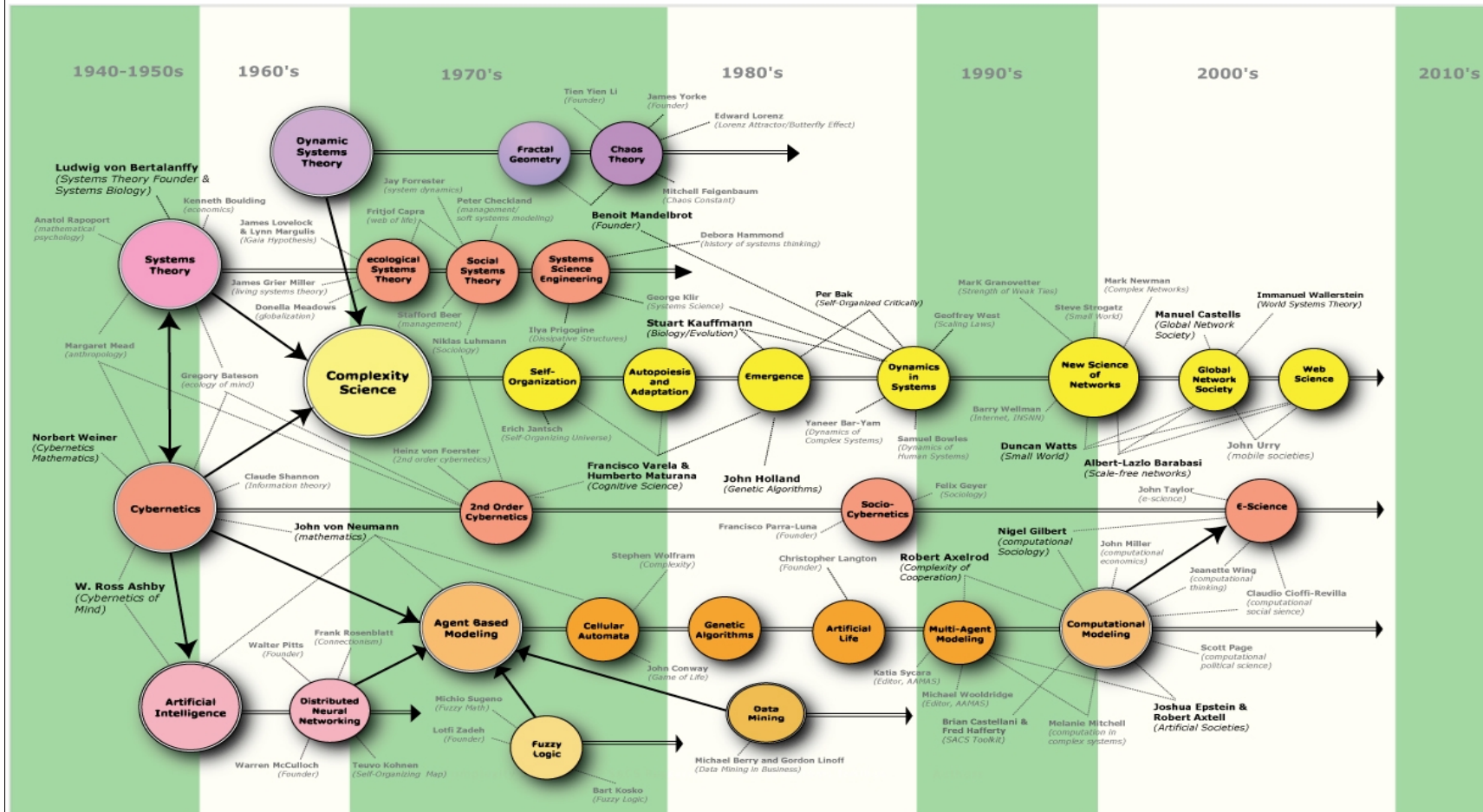
SYSTEMS STUDY

Complexity Human necessity to deal-with (simplify) the complexity in the problem-space

Simplification of Science -&- Science of Simplification
Combinatorial Complexity

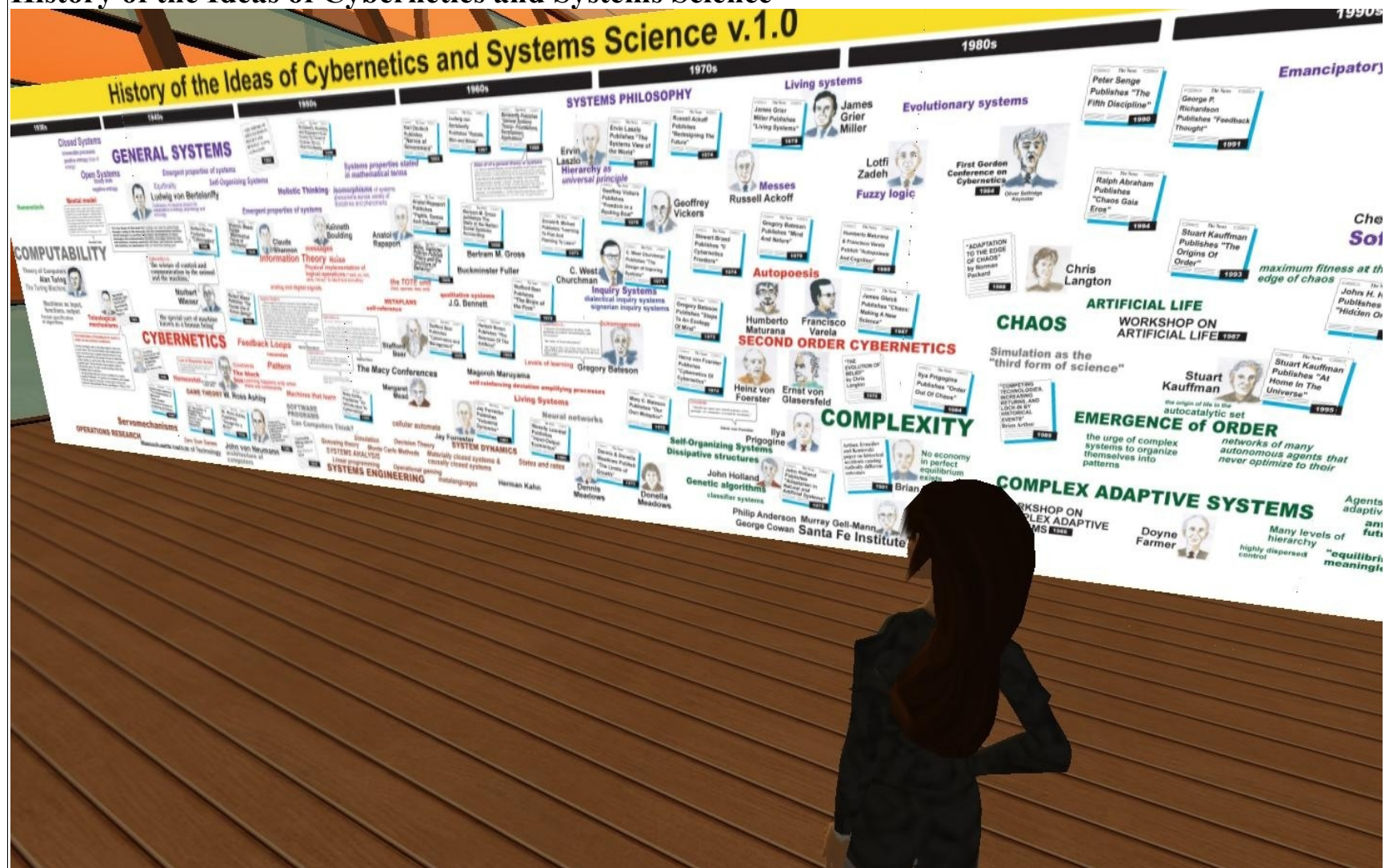
Organized-Complexity
(Systems Approach)

Unorganized-Complexity
(Statistical Approach)



SYSTEMS STUDY

History of the Ideas of Cybernetics and Systems Science



SYSTEMS STUDY

TIMELINE

- . . .
- 1820-1903 [Herbert Spencer](#)
- 1882-1950 [Nicolai Hartmann](#)
- 1848-1923 [Vilfredo Pareto](#)
- 1858-1917 [Emile Durkheim](#)
- 1922 [Alexander Bogdanov](#) publishes [Tectology](#) in Russian (German translation 1928, English 1980)
- 1929-1951 [Robert Maynard Hutchins](#), University of Chicago
- 1946-1953 [Macy conferences](#)
- 1948 [Norbert Wiener](#) publishes *Cybernetics or Control and Communication in the Animal and the Machine*
- 1955 [W. Ross Ashby](#) publishes *Introduction to Cybernetics*
- 1956 [Ludwig von Bertalanffy](#), [Anatol Rapoport](#), [Ralph W. Gerard](#), [Kenneth Boulding](#) establish Society for the Advancement of General Systems Theory.
- 1968 [Ludwig von Bertalanffy](#) publishes *General System theory: Foundations, Development, Applications*
- 1970-1980s [Second-order cybernetics](#) developed by [Heinz von Foerster](#), [Gregory Bateson](#), [Humberto Maturana](#) and others
- 1970s [Catastrophe theory](#) ([René Thom](#), [E.C. Zeeman](#)) Dynamical systems in mathematics.
- 1980s [Chaos theory](#) [David Ruelle](#), [Edward Lorenz](#), Mitchell Feigenbaum, [Steve Smale](#), James A. Yorke
- 1986 [Context theory](#) [Anthony Wilden](#)
- 1988 [International Society for Systems Science](#)
- 1990 [Complex adaptive systems](#) (CAS) [John H. Holland](#), [Murray Gell-Mann](#), [Harold Morowitz](#), [W. Brian Arthur](#)
- . . .

SYSTEMS STUDY

WHAT IS A SYSTEM ? (my definition)

A system is an **object/phenomenon/entity** (with an *identity* of its own) that is an **integral/holistic organization/assemblage of inter-active/inter-related/inter-dependent components/units/elements/parts**, manifesting an **emergent overall system-behavior/property/feature/characteristics**, and identifiable with an overall system-function/goal/purpose.

System can be either abstract/conceptual or concrete/physical.

SYSTEM CHARACTERISTICS:

**Inter(actions)relations / interdependence among the Component Sub-systems
{Systemic inter-actions/inter-relations / inter-dependences }**

Emergent Properties (system properties)

**arising from the interactions among the Component Sub-systems
which are not easily discernible from a study of the individual components**

Components	Inter(actions)/relationships/Interdependence
Boundary	Environment Interface Input - Output
System-Function / Goal / Purpose	Constraints (internal/external)

Systems Studies Life Cycle - A Problem Solving Scenario

Detection / Description

Identification / Classification

Representation / Formulation / Modeling

Solution: Analysis / Simulation / Synthesis / Design / Optimization / Control

Testing / Interpretation / Evaluation

Implementation

System Concepts

System-Description System-Classification

Structure / Form -&- Behaviour / Function

System States -&- State Transitions System-Identity

Process / Transformation

Performance Characteristics/Measures/. . .

Dynamics – Regulation / Adaptation / Control / Stability / Equilibrium / Convergence / . . .

Decomposition Modularity Coupling Cohesion

SYSTEMS PHILOSOPHY SYSTEMS THEORY SYSTEMS METHODOLOGY SYSTEMS APPLICATIONS

SYSTEMS STUDY

What How (Why) Where When Which / Who ...

General Scientific & Systemic Concepts

- A World View : A grand paradigm including the beliefs and philosophical preferences of the general scientific community.
- A Paradigm : A common way of thinking, held by the majority members of a specific scientific community.
- A Theory : A broad coherent assembly of systematic explanatory schemes, consisting of Laws, Principles, Theorems, etc.
- A Law : A generalization founded on empirical evidence, well established and widely accepted over a long period of time.
- A Principle : A generalization founded on empirical evidence, but not yet qualifying for the status of a Law.
- A Theorem : A generalization proven in a formal mathematical/logical way.
- A Hypothesis : A proposition which is intuitively considered to be true but which has to be verified & confirmed or falsified.
- An Axiom : Impossible to prove or deduce from some thing else, but is a starting point for the hierarchy of scientific abstractions presented here.
- An Idea : Anything that flashes to a human mind/intellect (specifically an idea that is possibly useful with respect to the above hierarchy).

SYSTEMS STUDY

LAWS

Laws of Motion;

Laws of Thermodynamics;

Law of Complementarity (Weinberg 1975)

Law of Requisite Variety (Ashby 1964)

Law of Requisite Hierarchy (Aulin & Ahmavaara 1979)

Law of Requisite Parsimony (Miller 1956)

THEOREMS

Godel's Incompleteness Theorem

Recursive System Theorem

AXIOMS

Axiom of Experience

Simplification of Science & Science of Simplification

PRINCIPLES

System Holism Principle

Suboptimalization Principle

Darkness Principle

Hierarchy Principle

Redundancy(of Resources)-Reliability Principle

Relaxation Time Principle

Equifinality : Negative Feed Back Causality Principle

Multifinality : Positive Feed Back Causality Principle

Homeostasis : Regulation/Adaptation Principle

Equilibrium : Steady State Principle

Self-Organizing Systems Principle

Basins of Stability Principle

Viability Principle

Cybernetic Control Principles

Feed Back Principle

Principle of Invariance

SYSTEMS STUDY

SOME ISSUES OF CONCERN

Missing the relevant detail (Signal) -and/or- Picking the irrelevant detail (Noise)

Observer – Observation – Observed : Scope, Resolution/Granularity

Modeling Errors - Implicit / Hidden Assumptions

Errors of Decomposition -&- Errors of Composition

Complementarity - Interdependence, Self-Reference / Circularity / non-Transitivity

Performance: Robustness, Reliability, Efficiency, Safety, . . .

Dynamics: Regulation, Adaptation, Control, Stability, Equilibrium, Convergence

Optimization

Uncertainty

. . .

SYSTEMS STUDY

Effect of GRANULARITY on Symmetry Properties

Palindrome-String : String-Sf = String-Sr

S↓ p→	p1	p2	p3	p4	p5	p6	p7	p8	p9
Sf:	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Sr:	Q9	Q8	Q7	Q6	Q5	Q4	Q3	Q2	Q1

Sf:	M	A	L	A	Y	A	L	A	M
Sr:	M	A	L	A	Y	A	L	A	M

S↓ p→	p1	p2	p3	p4	p5	p6	p7
Sf:	Escher	drawing	hands	drew	hands	drawing	Escher
Sr:	Escher	drawing	hands	drew	hands	drawing	Escher

Classification of the letter symbols of the English Alphabet, and the numerals
based on the (font-dependent) Symmetry Properties of the letter-symbols:

Subset1: {T, V, A, M, Y, W, U}

Subset2: {K, E, C, D, B; 3}

Subset3: {N, Z, S}

Subset4: {I, X, H, O; 0, 8}

Subset5: {L, F, J, P, R, G, Q; 1, 2, 4, 5, 6, 7, 9}

symmetry w.r.t. only Vertical-CL

symmetry w.r.t. only Horizontal-CL

only a 180-degree rotational symmetry

symmetry w.r.t. both Vertical-CL & Horizontal-CL

no symmetry

Symbol-Pairs: 69; 96; bq; qb; dp; pd; nu; un; ...

180-degree rotational symmetry

Self-reference / Circularity

- (1) “This sentence is False”
- (2) “This sentence contains seven words”
- (3) “This sentence does not contain seven words”
- (4) A: “Sentence-B is True” B: “Sentence-A is False”

Colin R. Blyth's Paradox

EXAMPLE:

A: rated 3-out-of-6 with 100% weightage.

B: rated 2-out-of-6 with 55% weightage, 4-out-of-6 with 25% weightage, 6-out-of-6 with 20% weightage.

C: rated 1-out-of-6 with 52% weightage, 5-out-of-6 with 48% weightage.

Given that higher rating indicates better preference.

Determine the rank-order-of-preference for deciding on the best, second-best and the third.

Three Approaches:

Compare the weighted average ratings for each of the candidate-choices A,B,C (evaluated one at a time);

{A=3.00, B=3.30, C=2.92}

Result: B>A>C.

Compare two at a time: (i) $P\{A > B\} = 0.55$, (ii) $P\{B > C\} = 0.616$, (iii) $P\{A > C\} = 0.52$;

Result: A>B>C.

Compare three at a time: (i) $P\{(A>B)\&(A>C)\}=0.286$, (ii) $P\{(B>A)\&(B>C)\}=0.330$, (iii) $P\{(C>A)\&(C>B)\}=0.384$;

Result: C>B>A.

SYSTEMS STUDY

Simpson's Reversal Paradox

	M	F		M	F		M	F	
S	11	70	+	80	19	=	91	89	S
R	9	30		20	1		29	31	R
	M	F		M	F		M	F	
S	1	5	+	20	9	=	21	14	S
R	19	45		30	11		49	56	R
	M	F		M	F		M	F	
S	1	5	+	45	19	=	46	24	S
R	19	45		5	1		24	46	R
	M	F		M	F		M	F	

	M	F		M	F		M	F	
S	10	30	+	70	40	=	80	70	S
R	30	70		30	10		70	80	R
	M	F		M	F		M	F	
S	50	25	+	15	30	=	65	55	S
R	50	25		35	70		85	95	R
	M	F		M	F		M	F	
S	6	11	+	9	4	=	15	15	S
R	4	9		11	6		15	15	R
	S	F		M	F		M	F	

Non-Transitivity !=>? Cycle /Circularity

Team-A : scores 100 always.

Team-B : scores 101 three-fourth-of-the-time and 97 one-fourth-of-the-time.

Team-C : scores 102 half-of-the-time and 98 half-of-the-time.

Team-D : scores 103 one-fourth-of-the-time and 99 three-fourth-of-the-time.

Higher score indicates better performance.

Weighted-time-average-scores:

$wtas-A = wtas-B = wtas-C = wtas-D = 100.$

$P\{A < B\} = 0.7500; P\{B < A\} = 0.2500;$

$P\{A < C\} = 0.5000; P\{C < A\} = 0.5000;$

$P\{A < D\} = 0.2500; P\{D < A\} = 0.7500;$

$P\{B < C\} = 0.3750; P\{C < B\} = 0.6250;$

$P\{B < D\} = 0.5625; P\{D < B\} = 0.4375;$

$P\{C < D\} = 0.3750; P\{D < C\} = 0.6250;$

Observe the cycles arising from non-transitivity:

$(A < B < D < A);$

$(D < C < B < D);$

SYSTEMS STUDY

Some Suggested References

- (1) <http://pespmc1.vub.ac.be/DEFAULT.html> Principia Cybernetica Web
- (2) <http://iss.org/world/> International Society for the System Sciences
- (3) <http://www.ifsr.org/> International Federation for Systems Research
- (4) <http://systemtheory.net/>
- (5) <http://www.well.com/abs/>
- (6) <http://www.er.ele.tue.nl/sweiland/ssyst.htm>
- (7) <http://www.slideshare.net/joelogs/general-systems-theory-and-systems-analysis-presentation>
- (8) Ludwig Von Bertalanffy, “General System Theory – Foundations, Development, Applications”
- (9) Yi Lin, “General Systems Theory – A Mathematical Approach”
- (10) Gerald M. Weinberg, “An Introduction to General Systems Thinking”
- (11) Lars Skyttner, “General Systems Theory – Ideas & Applications”
- (12) Herbert A. Simon, “The Sciences of the Artificial”
- (13) George Klir, “Facets of Systems Science”

SYSTEMS STUDY

ADDITIONAL NOTES

SYSTEM CLASSIFICATION:

Discrete – Continuous; Open – Closed; Deterministic – Stochastic; Static – Dynamic; . . .

MODEL CLASSIFICATION:

Input-Output (Black-Box) Models; Mechanistic Models; Mathematical / Graphical / Verbal / Physical Models; . . .

Analysis Model; Simulation Model; Design Model; Optimization Model; Control Model; . . .

SOME GENERAL SYSTEMS LAWS:

Law of Complementarity: Two different perspectives/models that are neither entirely independent nor entirely compatible.

Law of Requisite Variety: Control can be achieved only if the variety of the controller is at least as great as the variety of the situation to be controlled.

Law of Requisite Hierarchy: Weaker or uncertain regulatory capability requires more stronger hierarchical structure in the system to achieve similar performance goals.

Law of Requisite Parsimony: Human short term memory is limited by the number of basic chunks/units (7plusORminus2)

System Holism Principle: A system has holistic properties not manifested by any of its parts; the parts have properties not manifested by the system as a whole.

Suboptimization Principle: Optimization of each of the component subsystems need not necessarily result in optimum system.

Darkness Principle: No system can be known completely.

Hierarchy Principle: Complex natural systems are organized in hierarchies wherein each level may consist of several component subsystems.

Redundancy(of Resources)-Reliability Principle: Maintenance of stability under conditions of disturbances requires redundancy of critical resources. Generally, arithmetic increase in redundancy yields geometric increase in reliability.

Relaxation Time Principle: System stability is possible only if the system relaxation time is shorter than the mean time between disturbances.

Equifinality – Negative Feedback Principle: With negative feedback, the system can achieve equilibrium that is invariant over a wide range of initial conditions.

Multifinality – Positive Feedback Principle: With positive feedback, radically different end-states are possible from the same initial conditions.

SYSTEMS STUDY

Homeostasis Principle: A system survives only so long as all essential variables are maintained within the limits of their regulatory and or adaptation capabilities.

Steady-State-Equilibrium Principle: Steady-State-Equilibrium of a system implies and is implied by the simultaneous equilibrium of all its subsystems.

Self-Organizing Systems Principle: Complex systems organize themselves and their characteristic structural and behavioral patterns are mainly a result of interaction between the subsystems.

Basins of Stability Principle: Complex systems have basins of stability separated by thresholds of instability; a system dwelling on a ridge may suddenly return to the state in a neighborhood basin.

Viability Principle: Viability is a function of the proper balance between autonomy of subsystems and their integration within the whole system; or of the balance between stability and adaptation.

First Cybernetic Control Principle: Successful implicit control must be a continuous and automatic comparison of behavioral characteristics against a standard; followed by continuous and automatic feedback of corrective action.

Second Cybernetic Control Principle: In implicit control, control is synonymous with communication.

Third Cybernetic Control Principle: In implicit control, variables are brought back into control in the act of, and by the act of, going out of control.

Feedback Principle: The result of behavior is always scanned and its success or failure modifies future behavior.

Principle of Invariance:

Principle of Invariance: For any system, there are state transitions that preserve the invariance of any given system attribute, and there are system attributes that remain invariant with respect to any given state transition.

THEOREMS:

Godel's Incompleteness Theorem: All consistent axiomatic foundations of number theory include undecidable propositions.

Recursive-System Theorem: In a recursive organizational structure, each viable system contains, and is contained in, a viable system.

POSTULATES:

Postulates of General Systems Theory (Kenneth Boulding 1964):

Order, regularity and non-randomness are preferable to lack of order or to irregularity (chaos) or randomness.

Orderliness in the empirical world makes the world interesting and attractive to the Systems Theorists.

There is order in the orderliness of the empirical world (order of second degree) – a law about laws.

To establish order, quantification and mathematization are highly valuable aids.

SYSTEMS STUDY

The search for order and law necessarily involves the quest for those realities that embody these abstract laws and order, that is their empirical referents.

BASIC ASSUMPTIONS (Downing Bowler 1981):

The empirical world is a hierarchy of systems; that is, simple systems are synthesized into more complex systems, from subatomic particles to civilizations.

All systems, or forms of organization, have some characteristics in common, and it is assumed that statements concerning these characteristics are universally applicable generalizations.

All levels of systems have novel characteristics that apply universally upward in the hierarchy to more complex levels but not downward to simpler levels.

It is possible to identify relational universals that are applicable to all systems at all levels of existence.

Every system has a set of boundaries that indicates some degree of differentiation between what is included and excluded in the system.

Everything that exists, whether formal, existential, or psychological, is an organized system of matter, energy and information.

The universe consists of processes synthesizing systems of systems and disintegrating systems of systems. It will continue in its present form as long as one set of processes does not eliminate the other.

AXIOMS:

Axiom of Experience: Any/Every General Systems Theory Concept is a result of abstractions from human experience of the empirical world.

Axiom w.r.t. Simplification of Science -&- Science of Simplification: Human limitations in comprehension necessitates the simplification of science, and human rationality requires the science of simplification.

DEFINITION OF A SYSTEM (Russel Ackoff 1981):

A system is a set of two or more components that satisfies the following three conditions -

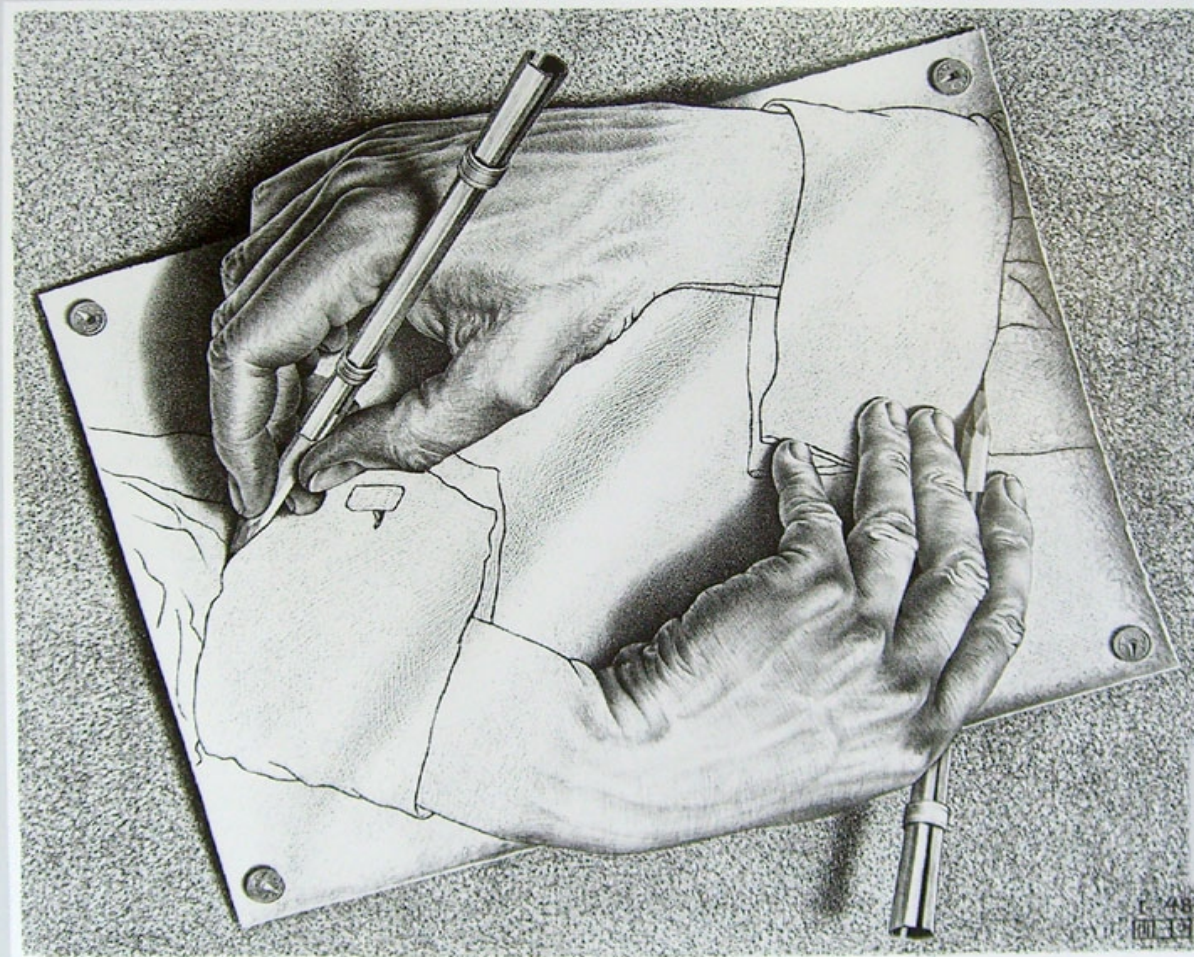
The behavior of each component has an effect on the behavior of the whole.

The behavior of the components and their effects on the whole are interdependent.

However subgroups of the components are formed, all have an effect on the behavior of the whole, but none has an independent effect on it.

SYSTEMS STUDY

ESCHER DRAWING HANDS DREW HANDS DRAWING ESCHER



M. C. E S C H E R

ESCHER DRAWING HANDS DREW HANDS DRAWING ESCHER

SYSTEMS STUDY

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